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Effects of Tree Distribution and Canopy Cover on Classification of Ponderosa Pine Forest from LANDSAT-1 Data[1]

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Many factors confound computer-assisted classification of forest types from LANDSAT-1 digital data in a mountainous area of central Colorado. Tree distribution and variable forest canopy cover were considered in this study to determine if classification could be improved by accounting for these factors.

Keywords: Forest classification, computer mapping, remote sensing

Introduction

Several studies have been made on computer-assisted mapping of forest cover types from LANDSAT-1 data. Krumpe et al. (1973) found LANDSAT-1 data could be used in the classification of vegetation types for a forest test site in California. However, not all attempts to map vegetation from satellite data have been as successful. Hoffer and LARS Staff (1973) identified several sources of error contributing to wide variations in spectral signatures, possibly because of slope, aspect, and plant canopy cover. Driscoll et al. (1974) found that adjusting the spectral signature of a ponderosa pine (*Pinus ponderosa* (Laws Dougl.) forest for slope improved classification accuracy. All of these investigators concluded that much research is needed to investigate the many ground-associated factors influencing computer-assisted analysis of remote sensing data.

In addition, these early studies showed that variations in sun altitude and azimuth can affect the spectral reflectance from forest canopies and confound classification accuracies (LeSchack 1971). Hoffer and LARS Staff (1973) found aspect, slope, and crown cover could be correlated with the reflectance of light from a forest canopy, thereby affecting classification accuracy. Since forests are comprised of continua for all of these factors, an understanding of the effect of each on spectral signature is necessary to improve classification accuracies.

Preliminary data on the effect of different combinations of slope, aspect, and cover of a ponderosa pine forest on the apparent reflectance of the LANDSAT-1 scanner produced significantly different response values. From these observations, we hypothesized that, by correcting for some of these factors, classification of that forest type could be improved.

There were two main purposes for conducting this study. The first was to investigate the effect of forest canopy cover and tree distribution on the apparent spectral signature from a single forest type, ponderosa pine. The second was to determine whether such factors could be corrected for to improve the accuracy of computer-assisted classification of forest types.

[1]*Work reported here was done in cooperation between the USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, and the Earth Resources Department, Colorado State University.*

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Methods and Materials

The study area was in and around the Manitou Experimental Forest in central Colorado, a typical area of the east slope of the Rocky Mountains with a variety of aspects and slope steepnesses.

A scene recorded on August 15, 1973, by the LANDSAT-1 multi-spectral scanner was analyzed in the form of digital values, each representing the instantaneous field of view of the scanner, approximately 79 m^2. The spectral response was measured by the scanner in four spectral bands: band 4 (0.5-0.6 μ), band 5 (0.6-0.7 μ), band 6 (0.7-0.8 μ), and band 7 (0.8-1.1 μ). These data are in the form of four arrays (one for each band) recorded on magnetic tape in a format compatible with computer processing systems.

A set of 24 sample plots of ponderosa pine forest on east-facing moderately steep (less than 8%) slopes was selected. The size of these plots corresponded to a 4 by 5 array of resolution elements in the digital satellite data representing a rectangular area approximately 315 by 395 m or 12.5 ha on the ground.

Two types of measurements were made on each plot. First, a computer processing system RECOG[3] by Smith et al. was used to determine the average spectral response in each of the 4 bands from the 20 resolution elements making up each plot. Second, the tree canopy cover for each plot was estimated by interpretation of 1:50,000 color infrared photos, flown at approximately the same time that the imagery was recorded.

[3]*Smith, J. A., G. Hartinger, and R. A. Mead. 1974. Computer applications support for ERTS investigation. Final Rep. Coop. Agreement 16-338-CA. Rocky Mt. For. and Range Exp. Stn., USDA For. Serv., Fort Collins, Colo. 28 p. (unpubl.)*

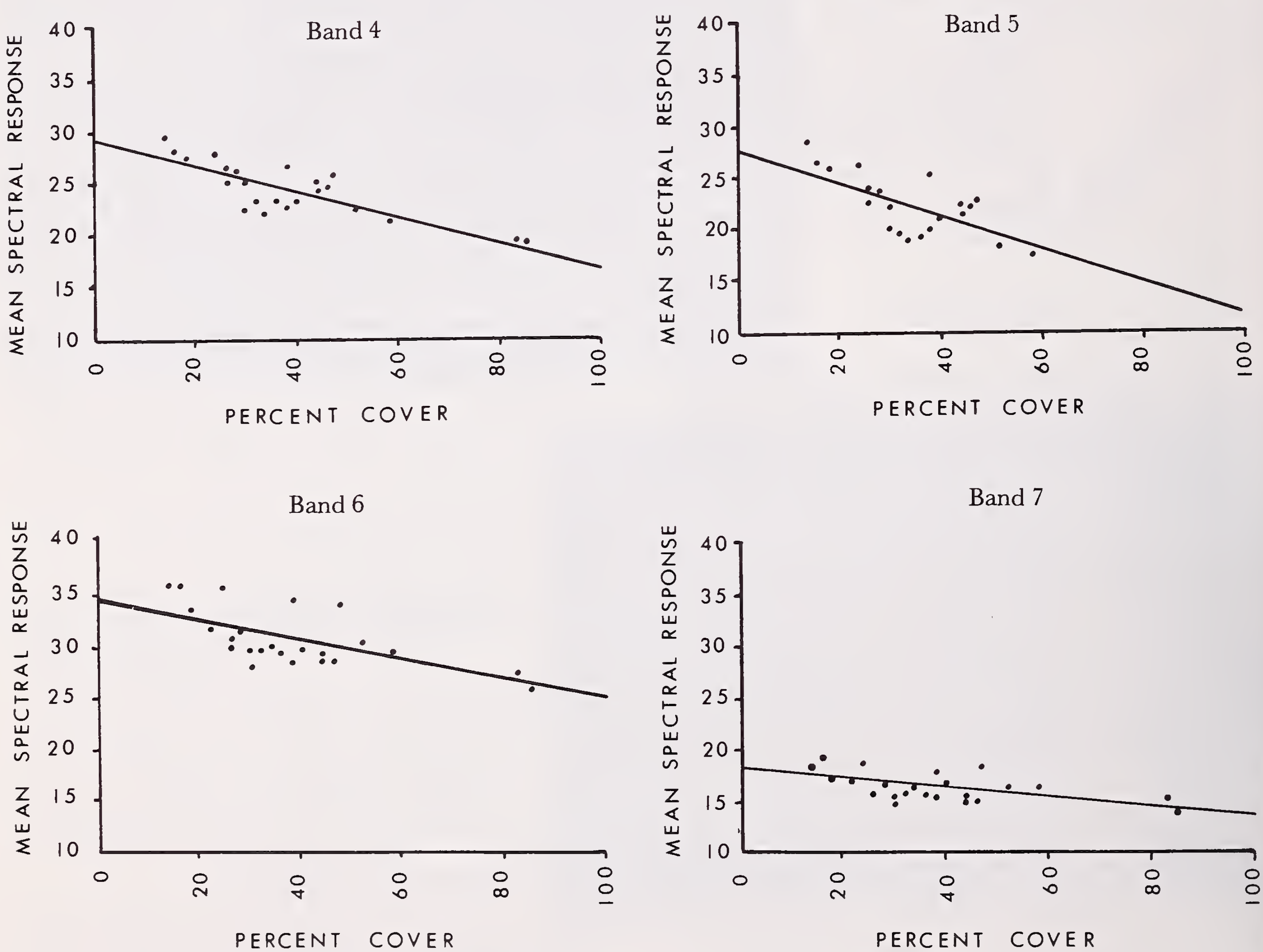

Figure 1. The mean spectral response of ponderosa pine forest on gradual (less than 8%) east-facing slopes as a function of percent tree canopy cover.

Results and Discussion

Tree canopy cover for the 24 plots of ponderosa pine forest varied between 14% and 84%, and the mean spectral response also varied considerably. Figure 1 displays the apparent relationship between the mean spectral response of the ponderosa pine forest plots in each band and percent tree canopy cover.

The following regression models were determined to describe the possible relationships between the mean spectral response, Y, and the tree canopy cover, X, in the four spectral bands:

$$Y = 29.11 - 0.12x : r^2 = 0.68; \text{C.I.} = 0.41 - 0.85 \text{ (band 4)}$$
$$Y = 27.86 - 0.16x : r^2 = 0.70; \text{C.I.} = 0.43 - 0.86 \text{ (band 5)}$$
$$Y = 34.49 - 0.10x : r^2 = 0.42; \text{C.I.} = 0.12 - 0.69 \text{ (band 6)}$$
$$Y = 17.93 - 0.04x : r^2 = 0.31; \text{C.I.} = 0.42 - 0.61 \text{ (band 7)}$$

The mean spectral response varied considerably because of changes in tree canopy cover, at least in bands 4 and 5. In general, the plots sparsely covered with trees had higher spectral responses than heavily forested plots. Gates et al. (1965) also found that coniferous plants have lower reflectances in both the visible and near-infrared than any of the other types of plants he measured.

The standard deviations of the signatures of each forest plot provided an interpretable relationship between the distribution of the trees within the plots and both the mean signature and the standard deviation of the mean signature. Plots with uniformly distributed trees had lower standard deviations than those in which the trees were grouped. For example, two plots of ponderosa pine forest (fig. 2) had similar tree canopy cover (26% and 28%) but tree distribution was very different. The standard deviations of the average spectral signatures for plot (a) in the four spectral bands were 2.41, 3.02, 3.19, and 1.34, while for plot (b), with more uniformly distributed trees, they were 0.86, 1.28, 1.23, and 0.74. In plot (a) some resolution elements represent the reflectance of predominantly non-forest vegetation, while others represent the reflectance from a dense forest canopy. Therefore, the digital values for individual forested and non-forested areas within plot (a) varied considerably from the overall mean for the plot. In plot (b), however, the area represented by each resolution element included a mixture of both forest and non-forest vegetation, and resulting intermediate values did not vary greatly from the mean.

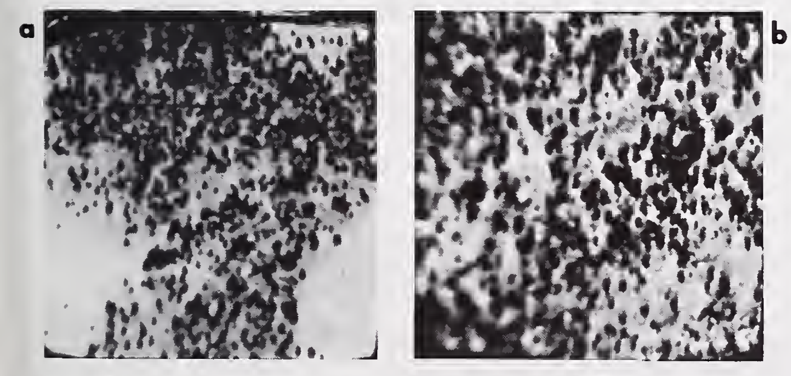

Figure 2. Although these two ponderosa pine forest plots have similar tree canopy cover, the trees in plot (a) are more clumped with open grassland between, resulting in higher standard deviations of the MSR, than in plot (b) in which the trees are more evenly distributed.

Comparing plots of ponderosa pine forest having similar total crown closure but varying tree distribution showed that the mean signatures could also vary significantly. Thus the distribution of vegetation within a sampling unit may affect the average signature as well as the standard deviation.

Conclusion

Many factors may account for the errors in classification of forest types from LANDSAT data. In this study we examined two of these factors: crown closure and tree distribution. It was found that plots of ponderosa pine with high crown closures generally had lower signatures than plots with low crown closure. Regression models were developed that adequately described this relationship for the two infrared bands of the LANDSAT data. Also, variations in tree distribution within plots can change the mean spectral response of ponderosa pine forest and thus classification accuracy.

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